

## COMPENSATING SHAFT FOR RECIPROCATING PISTON ENGINES

The invention relates to a compensating shaft for reciprocating piston engines with at least one compensating weight with an eccentric center of gravity, the compensating weight being connected torsionally elastically to the compensating shaft. In modern internal combustion engines, compensating shafts are used to reduce vibrations and running noises. However, their effect and success is satisfactory only when the compensating shaft unit itself also runs in a quiet and vibration-free way.

Vibrations of the compensating shaft unit can be excited by the moving masses of the engine and by its rotational irregularity. The latter are, on account of the clearances in their drive and the small torque transmitted via it, a noise source which is particularly difficult to control; moreover, great load with a changing sign is exerted on the teeth by virtue of the rotational irregularity. Minimizing the tooth clearances is problematic on account of the temperature differences arising and increases manufacturing costs enormously.

It is known to provide the driving toothed wheel on the crankshaft of the engine with an elastic connection between the toothed ring and the wheel body, for instance from US 3,667,317, but this isolation from excitation by the crankshaft allows the masses of the entire compensating shaft unit the freedom to vibrate.

It is furthermore known from JP 2000-283238 AA to provide a torsionally elastic connection between a compensating weight and a bushing made as a hollow shaft. This connection consists of rubber, which is fitted between claws in the interior of the compensating weight and external claws of the bushing.

It is therefore an object of the invention to achieve effective noise reduction in a compensating shaft unit by torsionally elastic connection to the compensating shaft with minimum manufacturing costs (simple assembly included). According to the invention, this is achieved by virtue of the fact that the compensating weight surrounds the compensating shaft with its edge zones (as described in WO 01/29447 A1) and a window is formed therebetween in the longitudinal direction, in which an elastic element is provided, which is supported on the compensating shaft in the circumferential direction. The connection is thus soft in the circumferential direction and hard in the radial direction, which is desirable on account of the unbalance. In addition to the other advantages, the window moreover allows enough space for a spring damper unit or for an elastic element made of plastic. The latter makes it possible to produce a compensating weight with a closed cylindrical contour, which minimizes its splashing losses. The fact that only the compensating masses themselves vibrate freely affords a reduction of the tooth entry impacts on the driving toothed

wheels and quieter running.

In an especially good development, the elastic element is made of plastic of elasticity which is graduated in the circumferential direction, the hard central part having a connection to the compensating shaft which is firm in the circumferential direction. Above all, this brings about a progressive spring rate, which firstly allows free dying out but secondly limits the amplitude.

In an advantageous embodiment, the plastic part is manufactured by injection molding, the connection to the compensating shaft consisting of a co-injected root projecting into a transverse bore of the shaft. This makes simple manufacture and rapid mounting of the plastic part in the compensating weight possible. For this purpose, the root can comprise a metal reinforcement.

The invention is described and explained below with reference to diagrams, where

Fig. 1 shows a first embodiment in an axonometric view;  
Fig. 2 shows a second embodiment in an axonometric view;  
Fig. 3 shows a third embodiment in an axonometric view, and  
Fig. 4 shows a section along A-A in Fig. 3.

In Fig. 1, a shaft is designated by 1 and a compensating weight by 2. The two together form a compensating shaft, which can also have more than one compensating weight 2. Here, the compensating weight 2 is of the type known from WO 01/29447, with two edge zones 3, which

surround the shaft 1 like suspenders, and an eccentric unbalance mass 4. A window 6 is thus formed on that side of the shaft 1 facing away from the unbalance mass 4. However, the compensating weight could also be of any other shape, for instance a closed eccentric body. It is essential that the compensating weight 2 is fastened on the shaft 1 with an elastic bushing 5 interposed. Here, the elastic bushing 5 is in the form of a cylinder jacket, which is cut out in the window 6. It is made from a material which is elastic above all in the circumferential direction, preferably a rubber-like plastic. The connection between the elastic bushing 5 and the surface parts bearing against it of the shaft 1 and the compensating weight 2 can take place in the usual way by bonding or vulcanizing.

In Fig. 2, similar parts are provided with a reference number increased by ten. The compensating weight 12 with its edge zones 13 and its eccentric unbalance mass 14 again has a window 16 here, which is formed by the inner surfaces of the edge zones 13 and the delimiting surfaces of the eccentric unbalance mass 14. In this window, a featherkey-shaped stop 15 can be seen, which is part of the shaft 11 or is connected firmly to it. Arranged between this stop and the delimiting surface 17 is a spring damper unit 18, illustrated only diagrammatically, which counteracts the relative rotation between the compensating weight 12 and the shaft 11 in one direction, a further such spring damper unit,